Behaviour of real gases: Deviations from ideal gas behaviour, compressibility factor, Z, and its variation with pressure and temperature for different gases.

Content Type	Notes
Status	Done
Chapter	Gaseous State
Course	Graduation
Reference	
Subject	Physical Chemistry
Topic	Compressibility Ideal Gas Pressure Real Gases Temperature
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Progress (%)	100
Difficulty Level	Medium
Mistake type	
Previous Year Questions	

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Behaviour of real gases

Some of the important behaviors of real gases include:

1. Deviation from ideal gas law: Real gases deviate from the ideal gas law (PV = nRT) at high pressure and low temperature due to intermolecular forces. The deviation can be described by the Vander Waals equation.
2. Compressibility factor: The compressibility factor of a real gas is the ratio of its actual volume to the volume predicted by the ideal gas law. The compressibility factor of a real gas is less than 1, indicating that its volume is smaller than that predicted by the ideal gas law.
3. Critical point: The critical point is the highest temperature and pressure at which a gas can exist in a liquid state. Beyond the critical point, the distinction between a gas and a liquid disappears.
4. Vapor pressure: Real gases have a finite vapor pressure, which is the pressure at which the gas begins to condense into a liquid. The vapor pressure of a real gas decreases with increasing temperature.
5. Diffusion: The diffusion of real gases is slower than that of ideal gases due to intermolecular forces and molecular size.
6. Adsorption: Real gases can adsorb onto surfaces due to intermolecular forces. The adsorption of gases can be used for separation processes and as a method for storing gases.

Deviation from ideal behaviour

Cause of deviation from ideal behavior of gas: Because of two important assumptions in Ideal gas:

- **Assuption**: Molecular Volume is negligible as compared to total volume of gas.
- **Reality**: Molecular volume is quite measurable and can not be ignored of gases
- **Assumption**: Gaseous Molecules have no force of attraction in between.
- **Reality** : Gaseous molecules have force of attraction between them.

Evidence of Molecular volume of gas

• Gases can be liquified and solidified in low temperature and High pressure.
• The gas liquified or solidified have some volume.
• This volume of gas is same irrespective of any state.
• liquified and solidified state of gases have force of attraction between molecule
• Solidified gases can be compressed up to certain extend only. Thus gases have appreciable volume, which is of same order as that occupies by same number of molecules in the solid state

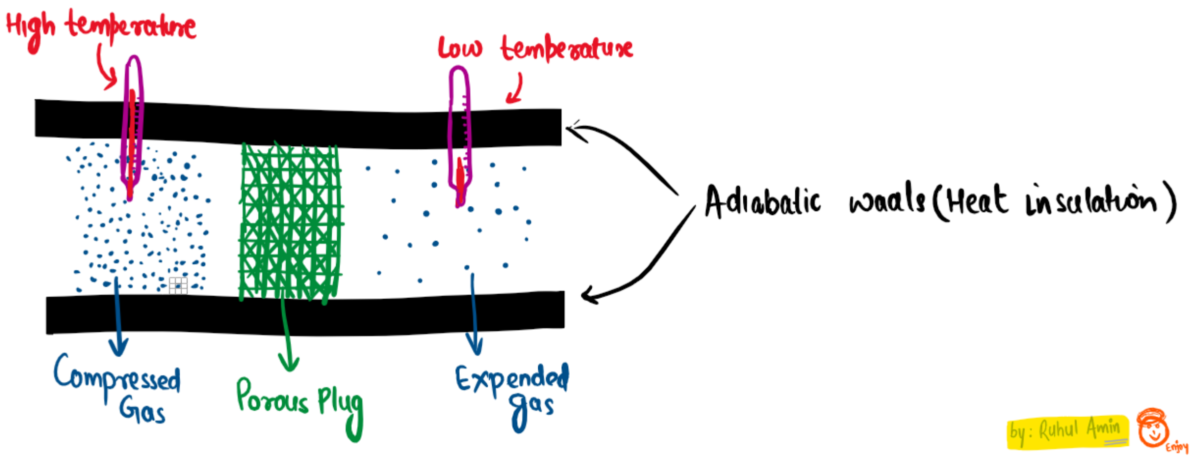
Evidence of Molecular Attration of gas:

• Gas molecules have vander waals force of attration,Otherwise gas could never be liquified or solidified.
• On liquification and solidification, we only tend to reduce kinetic energy (by lowing temperature) and reduce distance b/ w molecules (by high pressure).

> 💡 Molecular Attraction ultimately result in change in Pressure.

> Joule-Thomson effect is also the evidence.

Joule-Thomson effect



- When compressed gas is passed through porous plug in Adiabatic container the emerging gas is found to be cooler than entering gas
- This is because on expension, some work has to be done against the internal force of attraction, which require energy.
- This energy comes from the system itself.

Compressibility factor

→ $Z = \frac{PV_{real}}{RT}$ $PV_{ideal} = RT$

$Z = \frac{V_{real}}{V_{ideal}}$

→ $Z = 1$: Ideal gas

$Z > 1$: less compressible → eg: small molecule

↳ Volume factor dominates

$Z < 1$: More compressible.

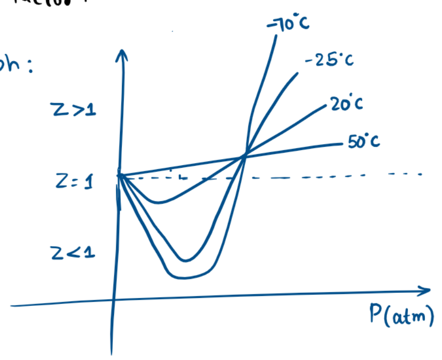
↳ Effect of Temperature on Compressibility factor:

Boyle's Temperature.

At particular temp, gas obay boyles law on certain range of pressure. This temp is called Boyle's temp.

↳ $T_B = \frac{a}{Rb}$

↳ Graph:



Compressibility Factor , also known as Z-factor, is a measure of the compressibility of a substance. It is used to describe the behavior of gases and vapors under different temperatures and pressures. It is defined as the ratio of the actual volume of a gas to the volume it would occupy at standard temperature and pressure (STP). The equation for the compressibility factor is:

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Z = {P V}/{n R T}
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where P is the pressure, V is the volume, n is the number of moles, R is the universal gas constant, and T is the temperature.

Another formula of Z is

$$Z = V_r / V_i$$

where Vr=Volume of real gas and Vi= Volume of ideal gas.

Positive , negative and zero deviation by compressibility factor

The compressibility factor, Z, can be used to describe the positive, negative, and zero deviations of a real gas from ideal gas behavior.

- A positive deviation occurs when the compressibility factor is greater than 1. This indicates that the real gas is more compressible than an ideal gas at the same temperature and pressure.
- A negative deviation occurs when the compressibility factor is less than 1. This indicates that the real gas is less compressible than an ideal gas at the same temperature and pressure.
- A zero deviation occurs when the compressibility factor is equal to 1. This indicates that the real gas behaves as an ideal gas, with no deviation from the ideal gas law.

In summary, the compressibility factor, Z, can be used to determine the deviation of a real gas from ideal gas behavior, with $Z>1$ indicating a positive deviation, $Z<1$ indicating a negative deviation, and $Z=1$ indicating a zero deviation.

Variation of compressibility with pressure

Fig 2.4 shows the compressibility factor Z, plotted against pressure for H2, N2 and CO2 at constant temperature.

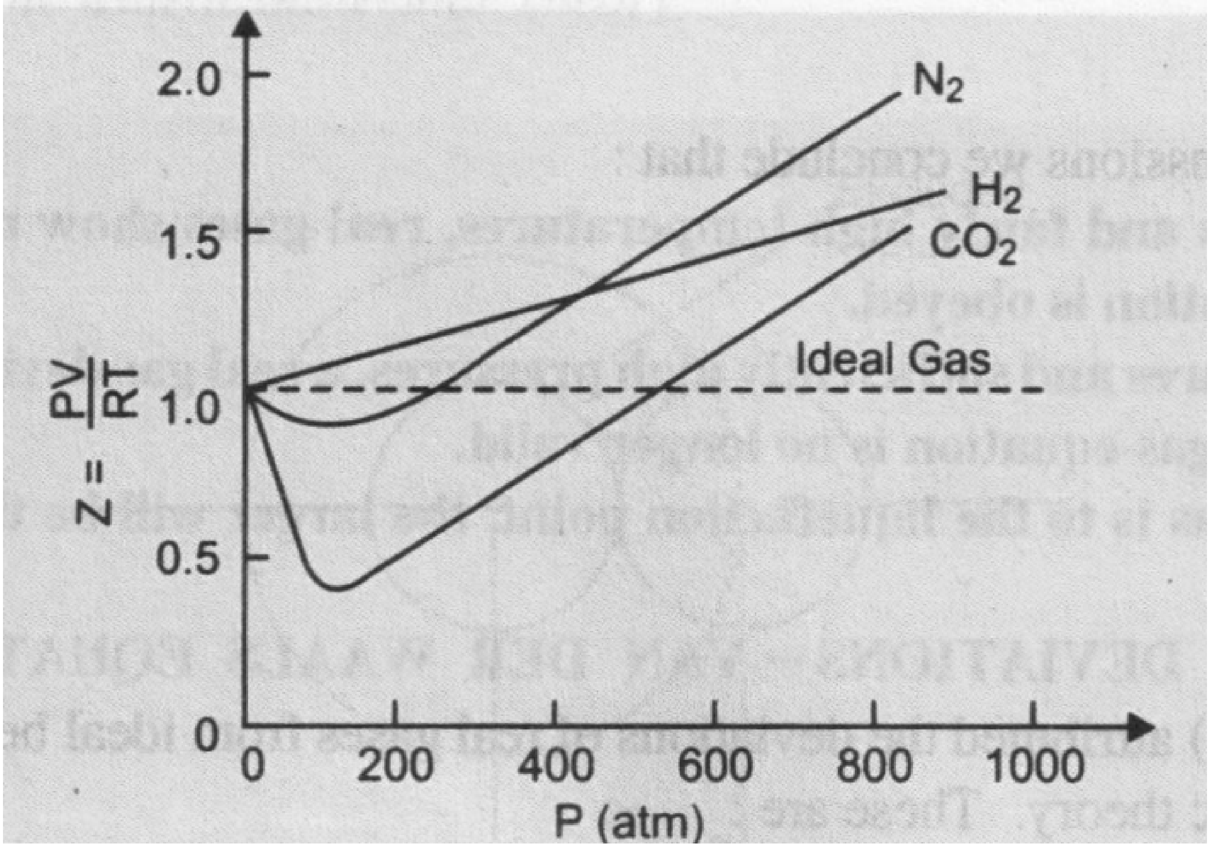

Fig 2.4

At very low pressure for all these gases Z is approximately one. This indicates that all real gases exhibit ideal behaviour (upto 10 atm). For hydrogen curve lies above ideal gas curve at all pressure. For nitrogen and carbon di-oxide, Z first decreases. It passes to a minimum then increases continuously with increase of pressure. For gas like CO2 the dip in the curve is greatest as it is most easily liquified.

Variation of compressibility with temperature

Fig 2.5 shows plot of Z against P at different temperature for N2.

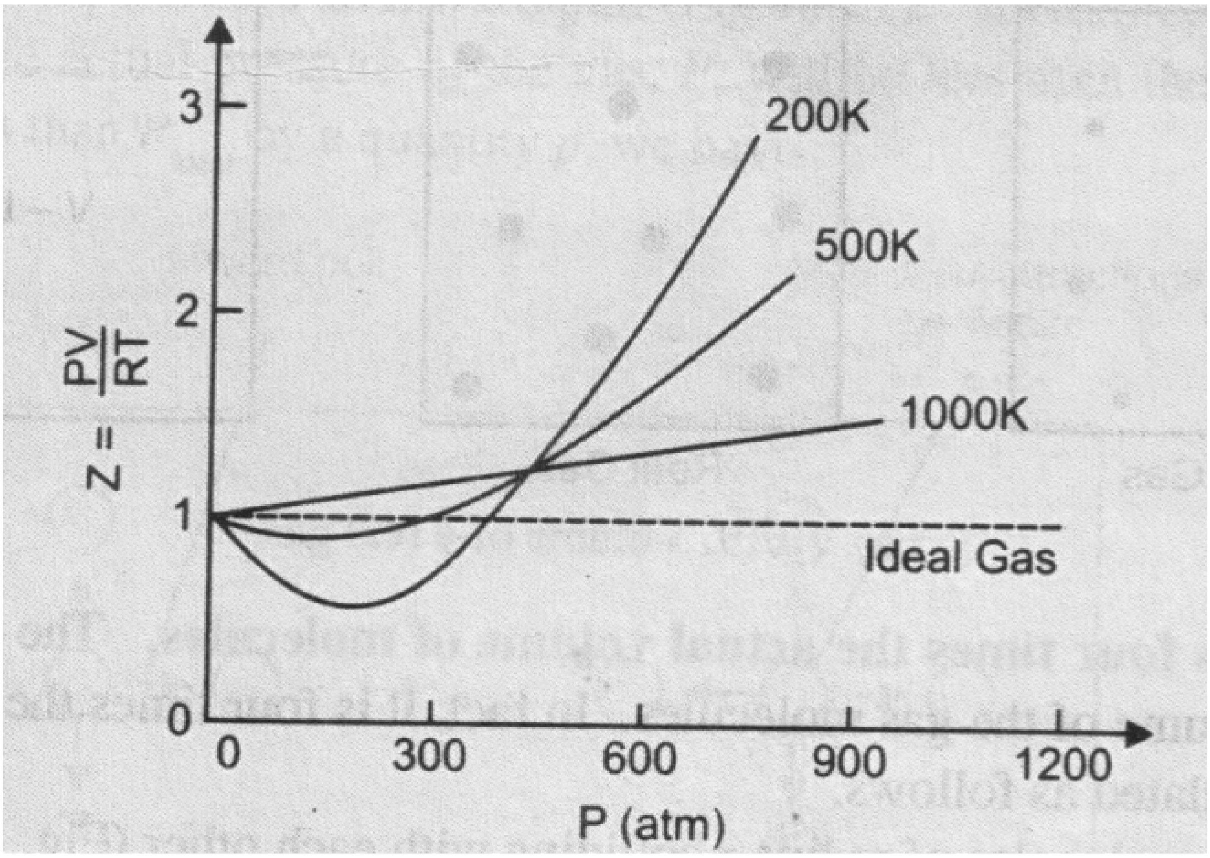

Fig 2.5

It is clear from the plot that at low temperature deviation are more and at high temperature the gas tends to become ideal.

> The relationship between compressibility and temperature can vary for different gases depending on their molecular structure and the strength of their intermolecular forces. For example, gases with strong intermolecular forces, such as nitrogen and oxygen, become less compressible as temperature increases, while gases with weak intermolecular forces, such as hydrogen, become more compressible.

Boyle's Temperature

It is the temperature at which the compressibility of a gas is constant and changes in pressure result in corresponding changes in volume.